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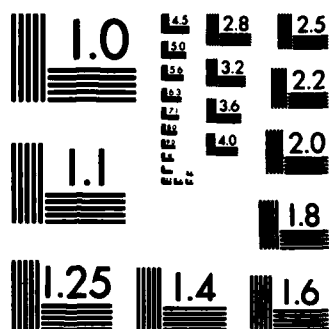
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Multiple Resources and Brain Laterality

Eugene H. Galluscio

Clemson University

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Multiple Resources

Summary. - Two studies were completed to test the multiple resources model of information processing using tachistoscopic lateralized-input techniques. In Exp. 1 37 normal, dextral subjects, 18 men aged 18-21 yr. and 19 women aged 18-22 yr. responded manually to a visuo-spatial and verbal dual-task presented simultaneously to left and right brain or non-laterally. Both men and women tended to have superior performance with coherent lateral input, however, differences in task difficulty and the possibility of a left to right scanning advantage with lateral input made interpretation of the data tenuous. In the second experiment the difficulty of the two tasks were made more equal and a third viewing condition, having noncoherent lateral input, was included. Twenty normal, dextral subjects, 10 men aged 18-21 yr. and 10 women aged 19-21 yr. were tested under all three viewing conditions. Both men and women had superior performance with coherent lateral input compared to the other two viewing conditions. The results were viewed as supporting the notion that each hemisphere has separate and unique pools of resources, that the resources of one or both hemispheres may be functional in processing a given task, and that in dual-task situations the brain operates most efficiently and accurately with direct access of appropriate tasks to each hemisphere.

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MATTHEW J. KERPER

Chief, Technical Information Division

The two hemispheres of the brain do not share identical functions. The left brain is more analytical and superior for the interpretation and production of language, while the right brain is more intuitive and is superior for the perception of space and form. Friedman and Polson (1981) have proposed a model of information processing based on these lateralized functions in brain. The model, which may be viewed as a special case of the multiple pools of resources model proposed by Navon and Gopher (1979), is based on the notion that each hemisphere has a unique, independent and mutually inaccessible pool of resources. Further, the model proposed that each hemisphere may process a given task with a strategy appropriate for its specific pool of resources; verbal and spatial strategies for the left and right hemispheres respectively. Friedman and Polson (1981) maintain, however, that few tasks require resources that are specific to only one hemisphere. Most tasks draw, to some degree, upon the resources of both sides of the brain and the proportions required may be varied experimentally by instructions, the choice of stimuli and methodological factors (e.g., Galluscio, 1983; Hannay, 1976). The model would predict that, as tasks approach specificity for unilateral resources, separate and

independent processing within each hemisphere should become more demonstrable.

If each hemisphere possesses a separate and somewhat unique resource pool, it would seem likely that independent and simultaneous access to each side of the brain could result in more efficient dual-task operations when the tasks selected draw primarily on the resources of each hemisphere. To maximize the potential for unilateral processing, however, several factors should be considered: (a) dextrals with no familial history of sinistrality have shown the largest and most consistent performance differences between the hemispheres (Levy & Reid, 1978), (b) gender should be accounted for since there is considerable evidence for gender differences in brain laterality (Galluscio, 1984; Seward & Seward, 1980), (c) tasks selected for each hemisphere should preclude, as much as possible, processing by the resources of the noncoherent hemisphere (Galluscio, 1983; Bagnara, et al., 1980), (d) the wide range of individual performance reported for lateralized tasks would warrant use of within-subject designs (Friedman & Polson, 1981).

In the two visual half-field experiments reported here, familial dextrals were required to attend to visuo-spatial

and verbal tasks presented either simultaneously to each hemisphere or nonlaterally. The tasks were specifically designed to maximize processing with the resources of one hemisphere and minimize alternative task strategies available to the contralateral hemisphere. Additionally, both men and women were tested to assess potential gender differences.

Experiment 1

Method

Subjects. - Participants in this study were 18 men aged 18-21 yr. and 19 women aged 18-22 yr. All were classified as strong dextrals based on a modified handedness questionnaire (Swiercinsky, 1978) and had no familial history of sinistrality. Subjects were tested for normal visual acuity, color vision, and right eye dominance (ABC vision test).

Apparatus and procedure. - A Gerbrands Model T-3-B three-channel tachistoscope, programmed to provide constant illumination at approximately 8 cd/m^2 , presented test stimuli for a 100 msec. duration. Each stimulus card contained two, bilaterally symmetrical, bold face letters (micrograma bold extended) and two dot matrices. The letters were random combinations of three vowels (A, O, U) and three consonants (T, H, V). A dot matrix was comprised of eight equidistant dots forming a pattern of two 3-dot columns and

one 2-dot column. Each letter and dot matrix was 15° arc h. by 1° arc w. The stimuli were positioned either with the letters above and the matrices below a central fixation point or with the letters to the right and the dots to the left of the fixation point. In both viewing conditions the letter pairs and the dot matrices were oriented vertically with the central edge of the stimulus pair $1\frac{1}{2}^{\circ}$ of arc from the fixation point.

The subjects were required to respond by pressing a telegraph key whenever a stimulus card had two identical dot matrices (spatial task) or when the letters were both consonants or both vowels (verbal task). When neither of the above conditions were present, no response was made. Reaction times and errors were recorded and both speed and accuracy were encouraged in the subject instructions. There were 144 stimulus cards in each viewing condition for a total of 288 trials. The cards were divided by vertical and side-by-side viewing conditions into 12 blocks of 24 cards each. Half of the trials had matches, 25% were verbal matches, and 25% were spatial matches. Half of the responses were made with the left and right hands. Response hand and viewing conditions were randomized by blocks of trials.

Results.

A summary of mean correct reaction times and error scores as a function of gender, stimulus orientation and task is shown in Table 1. There were no differences between right- and left-hand reaction times or errors, therefore, the hand responses were combined. Four women had false positive error rates above 50% making their reaction times questionable. A three-way analysis of variance for 18 men and 15 women with repeated measures on stimulus orientation and task was completed for the reaction times. The main effect for gender was not significant. The within-subjects effects for stimulus orientation ($F_{1, 31} = 4.63, p < .05$) and task ($F_{1, 31} = 18.55, p < .001$) were significant and there was an interaction effect for gender and task ($F_{1, 31} = 11.70, p < .01$). Compared to the women, men had more rapid reaction times for the spatial task with both lateralized input ($t_{31} = 1.82, p < .05$) and with the vertical stimulus orientation ($t_{31} = 1.85, p < .05$). Gender differences for the verbal task were not significant. As predicted, both men and women tended to be more rapid with lateralized input, however, the key comparisons to support multiple resources (e.g. spatial and verbal reaction times for men or women in the horizontal versus the vertical

viewing conditions) all failed to reach statistical significance at the .05 level of confidence. The interaction between gender and task reflects the tendency for women to be slightly more rapid on the verbal task and considerably slower on the spatial task.

An analysis of variance was completed for errors, including the error data for the four women subjects omitted from the reaction-time analyses. The main effect for gender was not significant. The within-subject effect for stimulus orientation ($F_{1,35} = 7.49, p < .005$), and task ($F_{1,35} = 90.83, p < .001$) were significant and there was an interaction effect for gender and task ($F_{1,35} = 8.01, p < .01$). Both men and women tended to make fewer errors with lateralized input compared to the vertical stimulus orientation. Men had significantly fewer errors on the spatial task with lateralized input ($t_{17} = 1.77, p < .05$) and women had significantly fewer errors on the verbal task ($t_{18} = 2.94, p < .005$). Both men ($t_{17} = 4.28, p < .001$) and women ($t_{18} = 8.75, p < .001$) had fewer verbal task errors than spatial task error with lateral input. Spatial errors were also higher with the vertical orientation for both men ($t_{17} = 4.10, p < .001$) and women ($t_{18} = 5.17, p < .001$). Men had fewer errors than women on the spatial task with lateral input ($t_{35} = 2.88, p < .005$).

and in the vertical viewing condition ($t_{35} = 1.88, p < .05$). Similar to the reaction time analyses, the interaction between gender and task reflects the tendency for women to perform better on the verbal task and less well on the spatial task than did the men.

Discussion

In a dual-task situation, simultaneous lateral input of a verbal task to left brain and a spatial task to right brain tended to reduce reaction time and errors on the two tasks for both men and women. Although this tendency for improved performance was consistent, the lateral input advantage was small and most of the cogent comparisons for reaction time and errors failed to reach statistical significance. Only the errors for men on the verbal task and for women on the spatial task showed a statistically significant advantage in the lateralized viewing condition. These data may be viewed as partial support for the multiple resources model of information processing. However, the large difference in difficulty between the verbal and spatial tasks prevents a clear interpretation. Reaction time and errors both indicate that the dot matrix task was more difficult in the two viewing conditions for men and women. This may have caused the subjects to apply useable resources from both hemispheres on

the spatial task, reducing the left-hemisphere resources available for processing the verbal task, thereby, decreasing the lateral input advantage (Friedman & Polson, 1981). This may be particularly relevant for women who have relatively poor spatial skills (Hartlage, 1970) and because they tend to use a verbal strategy for processing visuo-spatial tasks (Hannay, 1976). The poor performance of the women on the dot matrix task of this study is consistent with others (Kimura & Durnford, 1974; Levy & Reid, 1978) that have shown women to be disadvantaged on dot pattern tasks. Levy (1969) proposed that women perform more poorly on lateralized-input tasks because incomplete lateralization produces competing responses in each hemisphere. This could have been a factor for the four women whose reaction time data was eliminated due to excessive false positive errors.

At least one other interpretation of these data seems possible. It could be argued that some of the performance advantage observed in the lateral-input viewing condition could be attributed to the more customary horizontal orientation of the stimuli. That is, the subjects may have performed better with lateral input because they are more accustomed to processing information in the horizontal plane rather than vertically. It is not likely that a left to right

scanning advantage (White, 1969) would have been a factor in this study because of the brief (100 msec) stimulus duration and because the letters and dot matrices were paired vertically in both viewing conditions. This issue was addressed in Exp. 2.

Experiment 2

The results from the first experiment provided limited support for the multiple resources model of information processing. A clear interpretation of the data was not possible, however, because the two tasks were not of equal difficulty. It was suggested that the more difficult spatial task could have placed demands on the resources of both hemispheres thus reducing the advantage of coherent direct access to each side of the brain. Further, it was hypothesised that some of the performance advantage observed in the first study could have been attributed to the more customary horizontal orientation of the stimulus pairs. This study attempted to address these problems of interpretation by reducing the difficulty of the visuo-spatial task and by introducing a second horizontal viewing condition having the task half-fields reversed; spatial task directed to left brain and the verbal task directed to right brain.

Method.

Subjects. - The subjects in this study were 10 men aged

18-21 yr. and 10 women aged 19-21 yr. The selection procedure for the subjects was identical to that used in Exp. 1.

Apparatus and procedures. - The apparatus and procedures were the same as in Exp. 1. To make the spatial task easier the dot matrices were replaced by figures comprised of three horizontal bars; two long bars and one bar, half the length of the others. To be a match the short bar had to be located at the same level, top or bottom, and the same side, left or right, in both bar patterns. Stimulus duration was increased from 100 msec. to 150 msec. A second horizontal viewing condition was added having the spatial task in the right half-field and the verbal task in the left half-field. Subjects were given 144 trials in all three viewing conditions; vertical, horizontal coherent, and horizontal reversed, for a total of 432 trials. As in Exp. 1 the stimuli were presented in blocks of 24 by viewing condition. Blocks of trials and hand response were counterbalanced. Since high false positive responses in Exp. 1 made the reaction times of some subjects questionable, the subjects were instructed to avoid guessing and a 35% false positive rate was set as a cutoff for reliability on the correct reaction time responses.

Results.

The mean correct reaction times and errors as a function

of gender, stimulus orientation and task are summarized in Table 2. As in Exp. 1 there were no differences between right- and left-hand reaction times or errors, therefore, the hand responses were combined. Five of the women had false positive responses above 35% and their reaction times were not included in the analyses. The highest percentage of false positive responses for men was 16%. A three-way analyses of variance with repeated measures on stimulus orientation and task was completed for the reaction time data. There was a significant difference for stimulus orientation ($F_{2, 26} = 16.10, p < .001$) but no gender, task or interaction effects. Men had faster reaction times for the verbal task with coherent lateral input than in the vertical ($t_9 = 3.00, p < .01$) or reversed horizontal ($t_9 = 3.98, p < .005$) viewing conditions. There were no differences for women on the verbal task. On the spatial task men were more rapid in the coherent horizontal condition than in either the vertical ($t_9 = 1.83, p < .05$) or the reversed horizontal ($t_9 = 4.40, p < .005$) conditions. Women also tended to be more rapid on the spatial task with coherent lateral input compared to the vertical ($t_4 = 2.57, p < .05$) and the reversed horizontal ($t_4 = 2.15, p < .05$) conditions.

The number of false negative errors, particularly for the verbal task, were very small and the distributions clearly violated the assumptions of normality required for parametric tests. Therefore, an analyses of variance was not completed on the error data. Post hoc nonparametric tests were done on the relevant comparisons using the Mann-Whitney U-Test for independent samples and the Wilcoxon signed-ranks test for related samples. Men made more errors on the spatial task than the verbal task in the coherent lateral input ($T = 0$, $p < .005$) and the vertical ($T = 1$, $p < .005$) viewing conditions but not in the reversed horizontal condition. Women had higher spatial errors in all three viewing conditions; horizontal coherent ($T = 0$, $p < .005$), vertical ($T = 0$, $p < .005$), and horizontal reversed ($T = 0$, $p < .005$). Additionally, women had greater spatial errors compared to men in all viewing conditions; horizontal coherent ($U = 17$, $p < .01$), vertical ($U = 16.5$, $p < .01$), and horizontal reversed ($U = 19.5$, $p < .025$). Both men and women tended to have fewer verbal and spatial errors with coherent lateral input than in the other two viewing conditions. For men spatial errors were significantly lower with coherent lateral input than in either the vertical ($T = 1$, $p < .005$) or reversed horizontal ($T = 0$, $p < .005$) viewing conditions. Verbal errors for men were lowest with coherent lateral input

but were not significantly different than the other two viewing conditions. Spatial errors for women were lower with coherent lateral input compared to the vertical ($T = 9, p < .025$) and the reversed horizontal ($T = 6, p < .025$) viewing conditions. Women's verbal errors were also lower with coherent input compared to the vertical ($T = 1, p < .005$) and the reversed ($T = 1, p < .005$) viewing conditions.

The spatial task reaction times tended to be faster in this study compared to Exp. 1, however, only the women's times with coherent lateral input were statistically significant ($t_{18} = 1.88, p < .05$). Men had fewer spatial task errors in both the coherent horizontal ($U = 30, p < .01$) and the vertical ($U = 42, p < .05$) viewing conditions but spatial task errors for women did not differ significantly from Exp. 1. On the verbal task men were faster ($t_{26} = 1.94, p < .05$) and made fewer errors ($U = 52, p < .05$) with coherent lateral input, but women did not differ on the verbal task between the two experiments.

Discussion.

As was seen in Exp. 1, in a dual-task situation, coherent lateral input resulted in quicker reaction times and fewer errors. Performance with reversed lateral input (spatial task to left brain and verbal task to right brain) did not differ from performance in the nonlateralized vertical viewing

condition and was inferior to the coherent lateral-input condition. This clearly supports the notion that, in both studies, the performance advantage observed with coherent lateral input can be attributed to direct access of the appropriate task to each hemisphere and not to more efficient processing of visual information oriented in the horizontal plane. The bar pattern task was less difficult than the dot matrix task used in Exp. 1, however, it was still more difficult than the verbal task. This was particularly true for the women who, compared to the men, made significantly more errors on the spatial task in all three viewing conditions. This gender difference is likely due to lesser spatial abilities in women (Hartlage, 1970) and to the tendency for women to process visuo-spatial tasks with a verbal strategy (Hannay, 1976). Additionally, the women may have sacrificed the more difficult spatial task to concentrate on the verbal task. This could account for the high rate of false positive (guessing) responses made by the women in both studies. Verbal task performance for both men and women tended to be better in this study compared to Exp. 1. This may be attributed, in part, to the longer stimulus duration used in Exp. 2. It is interesting to note, however, that this difference was statistically significant only for men with coherent lateral input. Improved

performance on the verbal task is exactly what would be expected if some left-hemisphere resources, which had been allocated to the more difficult spatial task in Exp. 1, had been made accessible for the verbal task. Since only the men showed significantly fewer errors on the bar pattern task, it could be assumed that the smaller difference in verbal performance observed for women was due primarily to the longer stimulus duration. It is also possible that there may be a limiting ceiling effect for the women that precluded lower verbal errors in this study. Verbal errors for women with coherent lateral input were only 6.5% in Exp. 1 and 1.3% in this study, therefore, it appears there was little room to establish a statistically significant difference.

No response-hand advantage was observed in either study. The direct access model of laterality (Moscovitch, 1976; 1978) would predict an advantage for the hand contralateral to the hemisphere superior for the given task. Some investigators, however, have reported faster reaction times with the hand ipsilateral to the stimulus half-field independent of task (Berlucchi, et al., 1971) and others have reported no difference as a function of the hand making the response (Davis & Schmit, 1971; Filbey & Gazzaniga, 1969). There is some evidence for a

congruent hand response advantage in dual-task operations (Wickens, Mountford, & Schreiner, 1981), however, others suggest that motor related resources may be a limiting performance factor in dual-task situations (Gopher, Brickner, & Navon, 1982). Clearly more research is needed to clarify this issue.

The results of these studies support the notion that each side of the brain has separate and somewhat unique pools of resources, that the resources of one or both sides of the brain can be functional in processing a given task, and that in simultaneous dual-task situations the brain operates most efficiently and accurately with direct access of appropriate tasks to each hemisphere. Finally, it was shown that task difficulty and gender differences are important considerations when evaluating multiple resources using visual half-field procedures.

Table 1

Mean Correct Reaction Times (in msec.) and Percent Errors
as a Function of Gender, Stimulus Orientation and Task

Stimulus Orientation	Vertical		Horizontal	
	RT	% Error	RT	% Error
Men				
Verbal Task	1050	13.6	1032	12.0
Spatial Task	1120	44.6	1063	36.5
Women				
Verbal Task	1009	11.0	957	6.5
Spatial Task	1458	59.8	1393	58.9

Table 2

Mean Correct Reaction Times (in msec.) and Percent Errors
as a Function of Gender, Stimulus Orientation and Task

Stimulus Orientation	Horizontal Reversed		Vertical		Horizontal Coherent	
	RT	% Error	RT	% Error	RT	% Error
Men						
Verbal Task	1068	7.7	975	6.7	872	4.7
Spatial Task	1084	22.7	1123	23.3	962	10.7
Women						
Verbal Task	1072	6.0	961	6.3	980	1.3
Spatial Task	1044	53.0	1071	52.3	858	44.7

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